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13.1 INTRODUCTION

Figure 13-1 shows the flash card for Building Block 3.1: Suisun Marsh Tidal Wetland Restoration and Managed Wetland Enhancements.

13.1.1 Background: Suisun Marsh and Bay

Totaling nearly 116,000 acres, the Suisun Marsh (Marsh) is the largest remaining brackish wetland on the Pacific Coast of the United States and constitutes more than 10 percent of California's remaining wetlands (Brown 2004). The Marsh is located primarily in southern Solano County, between the confluence of the Sacramento and San Joaquin rivers in the western Sacramento–San Joaquin River Delta (Delta) (Figure 13-2). The boundaries of the Marsh were established by the Suisun Marsh Preservation Act of 1977 and can be described by the Montezuma Hills to the east, Suisun Bay to the south, Interstate 680 to the west, and State Route 12, Fairfield, and Suisun City to the north (SMCPA 2007). In addition to more than 50,000 acres of managed wetlands, the Marsh includes 30,000 acres of open water sloughs and bays, more than 7,000 acres of tidal marsh, and 27,000 acres of upland grasslands.

The variety of habitat types found within the Marsh, including tidal sloughs, brackish tidal marsh, diked managed seasonal brackish marsh, and upland grasslands, provide habitat for a variety of species. The Marsh is home to more than 221 bird species, 45 mammal species, 16 different reptiles and amphibians, and more than 40 fish species (SMCPA 2007). The Marsh also serves as a feeding and resting ground for resident and nesting birds as well as a significant portion of the migratory waterfowl using the Pacific Flyway migration route. Among the species found within the Marsh are a number of special-status species, including the salt marsh harvest mouse (*Reithrodontomys raviventris*), California black rail (*Laterallus jamaicensis cotorniculus*), California clapper rail (*Rallus longirostris obsoletus*), peregrine falcon (*Falco peregrinus),* and Swainson's hawk (*Buteo swainsoni*) (Table 13-1). Suisun Bay and its sloughs provide habitat and migration routes for endangered and sensitive fish species, such as chinook salmon (*Oncorhynchus tshawytscha*), Sacramento splittail (*Pogonichthys macrolepidotus)*, and Delta smelt (*Hypomesus transpacificus*). The area also supports a number of special-status plant species, including the Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*) and Suisun Marsh aster (*Aster lentus*), Delta tule pea (*Lathyrus jepsonii*), and soft bird's beak (*Cordylanthus mollis* ssp. *mollis*) (Table 13-1).

Historically, the Marsh consisted of a network of islands separated by tidal sloughs (Figure 13-3). The marsh was flooded daily by high tides and was seasonally (late winter and spring) inundated by high runoff volumes from Sierra snowmelt. The salinity in Suisun Marsh also varied along these patterns, with low salinity during the winter through early summer and high salinity during the low fluvial outflow season. Before the 1850s, the native vegetation was likely dominated by salt grass (*Distichlis spicata*) and a mix of tules (*Scirpus* spp.), cattails (*Typha* spp.), rushes (*Juncus* spp.), and pickleweed (*Salicornia* spp.) (Brown 2004).

The Marsh landscape has been extensively engineered to meet the needs of multiple stakeholders. Today, the Marsh includes approximately 230 miles of exterior levees that surround and protect over 50,000 acres of managed wetlands. Exterior levees (adjacent to sloughs and bays) are used in conjunction with interior levees, ditches, and water control structures to retain and control water and manage wetland habitats. Over the past 100 years, the Marsh has been managed to varying degrees with a recent focus on managing the area for wildlife habitat, with a focus on waterfowl populations.

In recent years, the ecological goals for the Marsh have expanded from a focus on waterfowl production and water quality management to the restoration of natural ecosystem processes and the protection of habitat for sensitive and native species. In 2000, the California Bay-Delta Authority (CALFED) Record of Decision called for the restoration or re-establishment of 5,000 to 7,000 acres of tidal wetland and the protection and enhancement of 40,000 to 50,000 acres of existing managed wetland habitats in Suisun Marsh (CBDP 2000). The CALFED Ecosystem Restoration Program (ERP) vision for the Suisun Bay and Marsh Ecological Management Unit is to restore tidal marsh and to restore and enhance managed marsh, riparian forest, grassland, and other habitats. According to the CALFED ERP, “to achieve this vision, the long-term future of Suisun Marsh levees and management of water quality with respect to both marsh management and Delta water supply are essential considerations” (CALFED ERP 2007).

13.1.2 Purpose and Scope of Building Block

The purpose of this building block is habitat enhancement and protection of existing wetland and wildlife resources, values, and functions. Its main purpose is not risk reduction, though some risk is mitigated. This report examines the benefits associated with tidal marsh restoration and managed wetland enhancement as well as the conceptual-level costs and reduction of risks. Cost estimates have been prepared for a set of potential conceptual restoration areas that meet, to varying degrees, the general selection criteria identified in Section 13.2.2. This report does not attempt to identify or recommend specific parcels of land for restoration; nor does it attempt to examine any of the four alternatives set forth in the development of the draft Suisun Marsh Habitat Management, Preservation, and Restoration Plan (known as the Suisun Marsh Plan [SMCG n.d.]) and associated Programmatic Environmental Impact Report/Environmental Impact Statement.

This report has been developed from a range of literature, including the draft Suisun Marsh Plan (SMCG n.d.), the draft Suisun Marsh Issue Memo (SMCPA 2007), Summary of 2004 Workshop: Making Science Work for Suisun Marsh (Brown 2004), communications with the California Department of Fish and Game (CDFG) and Suisun Resource Conservation District, and best professional judgment. It is a conceptual-level assessment that builds on existing knowledge to provide objective information that will be used to inform decision makers of the relative merits of large-scale tidal restoration in Suisun Marsh.

13.1.3 Objective and Approach

Over the past several decades, the diversity of management objectives for the Marsh has expanded dramatically and the regulatory environment affecting Suisun Marsh has become increasingly complex (Tables 13-2 and 13-3). Diverse land use management objectives have generated conflicts with ecosystem restoration and endangered species recovery programs. The need for an integrated approach to Marsh management and a balanced consideration of ecological processes and human uses led to the establishment of the Suisun Marsh Charter Group in 2000 and the initiation of a planning effort to develop the Suisun Marsh Plan (CALFED ERP 2007).

The approach of this analysis is to evaluate tidal marsh restoration in a manner consistent with the overall goals and objectives of the Suisun Marsh Plan and applicable state and federal regulations (Box 13-1, Table 13-3). To attain these goals, this report considers tidal marsh restoration together with enhancements to remaining managed wetlands within the Marsh.

Box 13-1 Goals of the Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh and Programmatic Environmental Impact Report/Environmental Impact Statement

Goal 1: Ecological Processes: Rehabilitate natural processes where feasible in Suisun Marsh to more fully support, with minimal human intervention, natural aquatic and associated terrestrial biotic communities and habitats in ways that favor native species of those communities, with a particular interest in waterfowl and sensitive species.

Goal 2: Habitats: Protect, restore, and enhance habitat types where feasible in the Suisun Marsh for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

Goal 3: Levee System Integrity: Provide long-term protection for multiple Suisun Marsh resources by maintaining and improving the integrity of the Suisun Marsh levee system.

Goal 4: Non-Native Invasive Species: Prevent the establishment of additional non-native species and reduce the negative ecological and economic impact of established non-native species in the Suisun Marsh.

Goal 5: Water and Sediment Quality: Improve and/or maintain water and sediment quality conditions to provide good water quality for all beneficial uses and fully support healthy and diverse aquatic ecosystems in the Suisun Marsh; and to eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

Goal 6: Public Use/Waterfowl Hunting: Maintain the heritage of waterfowl hunting and increase the surrounding communities' awareness of the ecological values of the Suisun Marsh. (Source: SMCPA 2007)

The specific objectives of this report are to:

- Identify at a conceptual level the managed wetlands and other diked lands that could be converted to tidal wetlands (See Section 13.2)
- Identify actions to enhance the remaining managed wetlands, including structural improvements to exterior flood control levees and the installation, repair, or replacement of water management structures, including water diversion systems and fish screens (see Section 13.2)
- Develop conceptual designs and discuss the value, benefits, and constraints of restoring tidal action to managed wetlands (see Section 13.3)
- Quantify a conceptual-level capital and operation and maintenance cost estimate with target acreages of tidal marsh restoration and managed wetland enhancements (see Section 13.4)

- Assess direct or indirect reductions in risk associated with large-scale restoration of tidal marshes and managed wetland enhancements, while acknowledging that the primary purpose of the building block is enhancement and not risk reduction (see Section 13.5)
- Discuss the costs and benefits of tidal restoration and managed wetland enhancement in Suisun Marsh and make recommendations on the merits of the building block (see Section 13.6).

13.2 CONCEPTUAL DEVELOPMENT OF IMPROVEMENT

13.2.1 Existing Conditions

Suisun Marsh is a mosaic of public and private lands, with more than 60 percent of the land privately owned (SMCPA 2007). Within the Marsh are approximately 38,000 acres of privately managed seasonal wetlands and 13,000 acres of land owned and managed by public agencies and land trusts (SMCPA 2007) (Table 13-4). The majority of Suisun Marsh, including wildlife habitat, lies at or below mean tide elevation. As a result, approximately 230 miles of levees are needed to provide flood protection to county and state lands, managed wetlands, infrastructure (including roadways, railroads, natural gas production, and transmission lines), residences, and natural resources (SMCPA 2007).

Approximately 7,600 acres of marsh are tidally inundated, including historical tidal marshes at Rush Ranch, Peytonia Slough, lower Joice Island, and East Hill Slough as well as a number of restored wetlands. Restored tidal marshes include Murphy #914, San Souci #901, Mastelotto #910, Taylor #801, Ryer Island, Roe Island, and Blacklock (Figure 13-4). Also, tidal wetland restoration projects are currently planned for Hill Slough West (CDFG, about 200 acres), Meins Landing (about 650 acres), and the Montezuma Wetlands projects (private, about 1,800 acres) (Brown 2004) (Figure 13-4).

13.2.2 Selection of Conceptual Restoration Sites

Due to the highly conceptual nature of this analysis, extensive spatial modeling and optimization procedures were not employed to select potential restoration sites. Instead, sites were identified based on a set of general criteria intended to maximize the likelihood of formation of tidal marsh or shallow water habitat, minimize negative impacts on existing infrastructure, and meet general targets of restored acreage identified by the 2000 CALFED Record of Decision (CBDP 2000) and the Suisun Marsh Plan (SMCG n.d.).

These criteria included:

- *Land surface elevation*: Using a raster map of land surface elevation, all Marsh land classified as below mean sea level (below 3.03 feet North American Vertical Datum of 1988 [NAVD88]) or at- or above-mean-sea-level diversion areas[1] with the majority of their land

[1] Diversion areas are units of land, most often separated by levees, within Suisun Marsh. These areas were used in this analysis as the smallest basic, integral, land unit.

surface at or above mean sea level were considered strong candidates for tidal restoration to expedite wetland vegetation establishment.

- *Connectivity with upland habitats*: The habitat complexity and diversity present along the transitional ecotone between high marsh plain and uplands provide refugia for a variety of sensitive wildlife species (including the salt marsh harvest mouse) and habitat for a variety of sensitive plant species. To establish or restore habitat connectivity with upland habitats, diversion areas abutting upland areas were considered strong candidates for tidal restoration.
- *Connectivity with existing tidal wetland habitats:* To establish or restore habitat connectivity with tidal wetland habitats, diversion areas near or adjacent to existing or planned tidal wetlands were considered strong candidates for tidal restoration.
- *Transportation infrastructure*: Regions with the lowest density of transportation infrastructure, including major roadways and railroads, were considered strong candidates for tidal restoration.
- *Land ownership*: Potential restoration sites were identified without consideration for land ownership.
- *Sediment sources*: Sites where the use of potentially available local sediment sources could be maximized to build a marsh plain and support emergent wetland vegetation (e.g., lands located around Little Honker Bay and Nurse Slough and east of Grizzly Bay) were selected. At these sites, winds cause unconsolidated bottom sediments to become suspended in the shallow water columns and to be transported into breached restoration sites.
- *Minimize salinity impacts to Delta:* Tidal restoration along the southern edge and southeastern quadrant of the Marsh was avoided because breaching those areas would increase the likelihood of increasing upstream Delta salinity. (However, it should be noted that tidal restoration and its associated larger tidal prism in Suisun Marsh may increase salinity and necessitate additional Marsh management.)

The 2000 CALFED Record of Decision (CBDP 2000) and Ecosystem Restoration Plan (CALFED ERP 2007) called for the restoration of 5,000 to 7,000 acres of tidal wetlands. The draft Suisun Marsh Plan considers four alternative scenarios for tidal marsh restoration, including a No Action Alternative (SMCG n.d.). These alternatives vary primarily in the extent of tidal marsh restoration (they range from 2,000 to 9,000 acres) and managed wetland enhancement (they range from 0 to 46,000 acres). To distribute tidal marsh restoration across the landscape, the Suisun Marsh Plan apportions target acreages across each of four management regions (Figure 13-5),[2] roughly according to the total area of each region. For the purposes of this analysis, a total restoration target was selected at the midpoint (5,500 acres), proportionately distributed across the four regions. Target acreages for each region are presented in Table 13-5.

[2] In the previous draft of this report, region designations 1 through 4 followed those in the draft planning documents (maps and tables) that CDFG provided to URS. However, the comments that URS received indicated that Regions 3 and 4 were mislabeled based on the most up-to-date planning information. In the current report, Regions 3 and 4 have been reversed to maintain consistency with the region designations of the draft Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (SMCG n.d.).

Contiguous or adjacent diversion areas that meet the above criteria were identified within each planning region. In some instances, it was not possible to identify land areas that meet all of these criteria. For example, much of Region 3 lies within heavily subsided Grizzly Island. As a result, it was difficult to identify tracts of land that were above mean sea level and adjacent to upland habitats.

13.2.3 Identification of Exterior Levees and Potential Breaches for Tidal Restoration

Exterior levees and potential flood zones (i.e., the area that would be flooded in the event of a breached levee) were mapped for all of the managed wetlands in Suisun Marsh based on expert opinion (Chappell, pers. comm., 2007). Using a digitized version of this map, the consulting team calculated the total length of existing exterior flood control levees for each conceptual restoration area. The total length was then distributed among:

- The length of exterior levees to be abandoned to achieve restoration of tidal action at each site
- The length of existing exterior levees to be upgraded to provide additional flood protection for managed wetlands on neighboring properties
- The length of new levees needed to provide additional flood protection for managed wetlands on neighboring properties (Table 13-6)

Levee improvements—upgraded levees and new exterior flood control levees—would be designed to the Suisun Marsh Levee standard (Appendix 13A).

The location and number of conceptual breach points for each conceptual restoration area were identified based on the historical location of tidal sloughs and channels (determined using maps of Suisun Marsh from the years 1902 and 1908) (Figure 13-3) (USGS Napa Quad and E.E. Douglas and R.B. Marshall Geographers). Two of the areas (in Regions 1 and 4) were not fed by channels large enough to be plotted on the historical maps. Therefore, levee lowering was prescribed for these two conceptual restoration areas assuming that tidal inundation would occur as sheet flow. Breach width calculations for the conceptual restoration area on Grizzly Island were estimated using the method described in Section 13.3.

13.2.4 Identification of Conceptual Areas for Managed Wetlands Enhancement

Of the 230 miles of exterior flood control levees in the Marsh, fewer than 20 miles (between Van Sickle Island and the mouth of Montezuma Slough) are eligible for levee maintenance assistance under the Delta Levees Subvention Program or the Special Projects Program (SMCG 2005). Maintenance of the approximately 210 miles of remaining exterior levees is the responsibility of local reclamation districts, private wetland managers, CDFG, and the Department of Water Resources (SMCG 2005). Also, of the approximately 425 individual water control structures (diversion, drains, and gates) currently in operation throughout the Marsh, fewer than 20 are fitted with screens to prevent entrainment of at-risk and listed fish (Figure 13-6). As a result, 40 percent (19,958 acres) of the 50,750 acres of managed wetland area in the Marsh has access to water from screened diversions (mostly on Grizzly Island; Figure 13-7).

In keeping with the Suisun Marsh Charter Group's goals of balancing public use and ecological processes and maintaining levee system integrity, a portion of the remaining managed wetlands (i.e., those wetlands not identified as conceptual tidal restoration areas) would be enhanced to provide long-term protection for multiple Suisun Marsh resources (Goal 3; Box 13-1). Managed wetland enhancement would include structural improvements to exterior flood control levees and the installation, repair, or replacement of water management structures (e.g., dual-purpose gates), fish screens, and ditch maintenance.

13.2.5 Analysis Results and Design Layouts

13.2.5.1 Conceptual Areas for Tidal Restoration

Using the general selection criteria and target acreages described in Section 13.2.2, conceptual areas for tidal restoration were identified in each of the four planning regions (Figure 13-8). For each planning region, the midpoint restoration target, total area of conceptual tidal restoration, length of abandoned flood control levees to achieve tidal restoration, length of exterior levees requiring upgrade to maintain flood control, and length of new flood control levees are given in Table 13-6 and depicted in Figure 13-8.

In Region 1, approximately 1,422 acres were identified for tidal restoration in the vicinity of Ibis Cut between Cordelia Slough and Frank Horan Slough (Table13-6, Figure 13-8). This area was identified for restoration based primarily on land surface elevation in the largely subsided region. Lying to west of the Southern Pacific railroad, little or no impact would occur to major transportation infrastructure. However, this site provides few opportunities for connectivity with upland habitats.

In Region 2, approximately 1,462 acres were identified for tidal restoration (Table13-6, Figure 13-8). One area, the eastern tip of upper Joice Island, provides an excellent opportunity to re-establish habitat connectivity with existing tidal wetlands across Cutoff Slough in Rush Ranch. Also, lands between Montezuma Slough and Nurse Slough provide excellent opportunities for connectivity with upland habitats. Potentially high sediment loads in Little Honker Bay and Nurse Slough would facilitate relatively rapid marsh plain accretion and intertidal emergent wetland formation after restoration of tidal action.

In Region 3, approximately 2,317 acres were identified for tidal restoration (Table13-6, Figure 13-8). The conceptual restoration area, located on Grizzly Island, at the eastern end of Grizzly Bay, provides habitat connectivity with approximately 500 acres of existing tidal wetland habitat wrapping the shore of the bay. The conceptual restoration area is located to the west of Grizzly Island Road; little or no impact would occur to major transportation infrastructure.

In Region 4, approximately 730[3] acres were identified for tidal restoration (Table13-6, Figure 13-8). Encompassing all of Bradmoor Island, the conceptual restoration area would provide connectivity with newly restored tidal habitat at Blacklock and existing tidal wetland habitat along the island's edge. Also, given the elevation rise to the center of Bradmoor Island, a

[3] Total land area of Bradmoor Island. Actual area of tidal wetland formation would be less given the presence of extensive upland habitat on the island.

significant opportunity exists for the formation of a transitional ecotone from tidal wetland to upland habitat.

13.2.5.2 Conceptual Areas for Managed Wetland Enhancements

Given the high recreational value of public lands on upper Joice Island (Region 2) and Grizzly Island (including the Grizzly Island Wildlife Area [Region 3]), these islands were identified for evaluation of conceptual-level costs associated with managed wetland enhancement. The length of perimeter levees to be upgraded to the Suisun Marsh Levee Specification standard was measured using geographic information systems (GIS). The total length of exterior levees for upgrade and the total area of managed wetland enhancements are presented in Table 13-7.

Two types of water management improvements were defined: replacement of water control structures and installation of new or replacement fish screens. A map of water control structures from the San Francisco Bay Delta Science Consortium (Figure 13-6) was used to identify locations and numbers of water control structures that may need upgrading over time. Water control structures are sized during detailed design based on flow and management needs. Due to the conceptual nature of this estimate, a generic gate type and gate size were selected: two 36-inch-diameter stainless steel combination gates with a single installed management access platform.

Fish screen costs are as complicated to compute as the costs of water control structures. Two of the major variables are fish species likely to be of concern and the flow intake velocity at the screen. The approach velocity guideline for Delta smelt is 0.20 feet per second. Table 13-7 presents the current number of fish screens for each of the managed wetland enhancement areas. These facilities may need to be replaced over time or additional fish screens may be required. Fish screen replacement or new installation costs are not quantified for this building block because the discussion of Building Block 3.3: Install Fish Screens (Section 15), presents these conceptual costs. The reader should refer to that discussion for further details.

The managed wetlands in the Marsh include many additional miles of levees that would require levee improvements over time. The identification of these levees, the prioritization of repairs or upgrades, and the selection of an engineering standard that would reduce risk in a cost-effective way could be performed in the future.

13.3 GEOMETRIC DESCRIPTION OF IMPROVEMENTS

Improvements required to restore tidal action may include levee breaching, levee lowering, starter channel construction, upgrade of existing exterior levees, and new levee construction. Improvements associated with managed marsh enhancement may include upgrade of exterior flood control levees, replacement of water control structures, and installation or replacement of fish screens.

13.3.1 Assumptions

Table 13-8 contains the tidal datum used in these conceptual design assumptions as modeled at a point in Montezuma Slough at the Suisun Slough Cut (DWR 2004). All assumptions discussed below would be subject to change during engineering design.

Levee Breach Geometry Calculations and Assumptions

- Total width of levee breach (in feet) was calculated for each region based on the relationship between channel width and potential tidal prism in Suisun Marsh (URS 2002) and other Bay locations.
- Approximate stored tidal prism was calculated for each region based on the total conceptual restoration area, the land surface elevation, and the mean high water elevation (5.02 feet NAVD88).
- Approximate crest elevations (in feet NAVD88) of exterior flood control levees were measured at select sites for each conceptual restoration area using 2006 LiDAR data (Table 13-9).
- Approximate land surface elevations (in feet NAVD88) immediately adjacent to flood control levees were measured at select sites in each conceptual restoration area using LiDAR data from 2006.
- All breach calculations are based on a levee crest width of 12 feet.
- Breach invert elevation is assumed to be mean lower low water (MLLW) (0.56 feet NAVD88).

As noted previously, two of the areas (in Regions 1 and 4) were not fed by channels large enough to be identified on historical maps of Suisun Marsh (Figure 13-3). Therefore, levee lowering was prescribed for these two conceptual restoration areas, and tidal inundation is assumed to occur as sheet flow.

Levee-Lowering Calculations and Assumptions

- Levee-lowering calculations assume that all abandoned flood control levees would be lowered to mean high water elevation (5.02 feet NAVD88).
- Levee-lowering calculations include levee crest elevations as stated above.
- All levee-lowering calculations are based on a levee crest width of 12 feet.

Channel Excavation Calculations and Assumptions

- The total area (in square feet) and total volume of starter channels for each region were calculated based on the total breach width (in feet) described above; the exact number and locations of the starter channels were not determined.
- Channel excavation calculations assume a (minimal) channel length of 250 feet.
- Channel excavation calculations include approximate land surface elevations as stated above.
- Channel excavation calculations are based on the amount of material to be excavated to mean low water (1.15 feet NAVD88).

Levee Upgrade Assumptions

- Levee upgrade calculations assume that existing perimeter flood control levees that serve as a boundary for a conceptual restoration area would be upgraded.
- Levee upgrade calculations assume that the crest elevation of all existing perimeter flood control levees is approximately 8 feet (NAVD88) based on the determination of the average levee height for Suisun Marsh in the Delta Risk Management Strategy Phase 1 Risk Analysis Report(URS 2008h).
- Construction cross-section geometry and designs are based on the Suisun Resource Conservation District Suisun Marsh Levee Specifications (Figure 13A-1 in Appendix 13A).
- Application of the Suisun Marsh Levee Specifications assumes that "zero tide" is equivalent to MLLW (0.56 feet NAVD88).

New Levee Construction Assumptions

- New levee construction calculations assume that new flood control levees would be constructed along the interior boundaries (i.e., areas formerly not subject to tidal action) of a conceptual restoration area (Figure 13-8).
- Construction geometry and designs for new levee construction are based on the Suisun Resource Conservation District Suisun Marsh Levee Specifications (Figure 13A-2 in Appendix 13A).
- Application of the Suisun Marsh Levee Specifications assumes that "zero tide" is equivalent to MLLW (0.56 feet NAVD88).

13.3.2 Description of Values, Benefits, and Constraints

Implementation of this building block could result in benefits from restoration of ecosystem processes and habitat creation. However, constraints could include reduction in managed wetland area and impacts on waterfowl hunting; availability of sufficient sediment supply to achieve elevations near mean high water for colonization of emergent wetland vegetation; water quality degradation, particularly by increasing salinity; impacts to infrastructure and other assets; and social/transaction costs.

13.3.2.1 Benefits: Restoration of Ecosystem Processes and Habitat for Marsh-Dependent Species

A primary goal of tidal wetland restoration in the Marsh is the restoration of ecosystem processes. Key ecosystem processes operating within the Marsh include salinity regulation, primary plant production, evapotranspiration, plant decomposition, nutrient cycling, and sedimentation and soil formation, to name but a few (Brown n.d.). Such processes function in a dynamic manner over varying spatial and temporal scales and make it extremely difficult to predict the effects of tidal wetland restoration (especially at the scale considered in this conceptual analysis). In some instances, restoration of natural processes may be both a benefit and a constraint (Brown 2004). On the one hand, the addition of organic carbon (resulting from the production and decomposition of plants and animals) to the food web may produce an increase in primary and secondary production. On the other hand, increased concentrations of dissolved organic carbon in the water can contribute to the potential formation of trihalomethane, which can be a concern for the quality of drinking water. Despite the scientific uncertainty, it is widely assumed that over time restoration of tidal wetlands would provide a net benefit for the Marsh, the Delta, and the organisms that depend on them. Additional research, monitoring, and modeling are required to predict the impacts of tidal restoration on ecosystem processes within Suisun Marsh.

During the past 150 years of management, the vegetation composition and habitat types within the Marsh have been significantly altered. Management practices (e.g., flooding, draining, and disking) and the introduction of and invasion by non-native species have altered habitat conditions for marsh-dependent native plants and animals. A primary goal of tidal wetland restoration in the Marsh would be the restoration (or re-creation) and enhancement of essential habitat for sensitive and native species. Because of variations in the existing ground surface elevations, restoration of tidal action to currently managed wetlands would likely produce a variety of habitat types, including open water, shallow water (sub-tidal), intertidal mudflat, tidal channel, tidal marsh, salt ponds, pannes, riparian, and upland transitional habitats.

Suisun Marsh is the largest brackish marsh on the Pacific Coast of the United States. Salinities in the Marsh vary seasonally from freshwater (during winter and spring) to approximately half-strength seawater (in the late summer and fall). The fish assemblage of the Marsh includes over 50 species; this assemblage also changes seasonally based on the timing of anadromous species' spawning runs and migrations and the response of transient species to seasonal changes in Marsh environmental conditions (Matern et al. 2002). In general, small, low-order dead-end sloughs in the Marsh provide habitat for the greatest diversity of rearing juvenile fish and may host greater densities of fish than are found in larger sloughs (Matern et al. 2002).

In recent years, most of the species in Suisun Marsh have been non-native; non-native species also dominate the total fish catch in the Marsh (Matern et al. 2002). By far the most abundant species caught in 21 years of regular sampling has been striped bass; two other non-native species, yellowfin goby and shimofuri goby, have accounted for significant percentages of fish caught. Still, the Marsh is considered to be among the best remaining aquatic habitats in the San Francisco Estuary for native species. This network of sloughs provides rearing habitat for many native fish species, including the Central Valley's four runs of chinook salmon, steelhead, Sacramento splittail, longfin smelt, tule perch, threespine stickleback, and tule perch (Matern et al. 2002). Another native and endangered species, the Delta smelt, occurs in the Marsh, but it has accounted for less than 1 percent of all the fish caught in the Marsh over 21 years of sampling by the University of California, Davis, Suisun Marsh survey (Matern et al. 2001).

Restoration of tidal marsh habitats in Suisun Marsh would have unknown and unpredictable impacts on the diversity and productivity of the Suisun Marsh fish assemblage. Indeed, the benefits of tidal marshes (restored, restoring, or remnant) to fishes of the San Francisco Estuary remain uncertain (Brown 2003). It is likely that impacts from tidal marsh restoration projects in the Marsh would vary from site-to-site depending on site proximity to freshwater and brackish water sources and their proximity to source sloughs with differing abundances and diversities of fish species. In general, tidal marsh provides little habitat to fish species because it drains (at least partially) on each tidal cycle. The degree to which tidal marshes augment sub-tidal habitats probably depends on the geometry of the inundated area (e.g., the area covered at various depths and the distance of the edge of the tidal marsh to sub-tidal habitat) and the biological development of the marsh site (e.g., the density of emergent marsh vegetation). Marsh geomorphology can determine whether a tidal marsh entrains aquatic organisms and acts as a population sink (e.g., Dean et al. 2005).

Tidal marshes are expected to have elevated rates of primary and secondary production compared with deeper sub-tidal habitats. Export of this primary and secondary production would be expected to benefit consumer organisms, such as fish and waterfowl; however, more documentation of this effect in the San Francisco Estuary is required. Also, it is not clear that food supplementation derived from tidal marshes would provide a net benefit to native fish species (Brown 2003); in the highly altered food web of the San Francisco Estuary, it is possible that non-natives would benefit more than natives from the primary and secondary productivity exported from restored tidal wetlands.

Delta smelt are found in low numbers in Suisun Marsh, because this species is generally found in pelagic waters. However, it is possible that larval Delta smelt may benefit from rearing in shallow, low-order sloughs, such as those found in parts of Suisun Marsh. Tidal marsh habitats are unlikely to provide direct habitat benefits to larval Delta smelt. These larvae are poor swimmers and would most likely suffer elevated mortality (from avian predators and stranding) during periods of tidal marsh residence. Delta smelt may benefit from increased food supplies in Suisun Bay, because some evidence indicates that Delta smelt in this estuary are food limited (Hobbs et al. 2006). To the extent that restoration of tidal marsh habitats in Suisun Marsh can supplement the food supplies of Delta smelt in adjacent pelagic habitats, such as Suisun Bay, this restoration may benefit Delta smelt populations overall, but numerous uncertainties exist in this relationship (Bennett 2005).

Tidal marsh habitats are also believed to benefit migrating chinook salmon juveniles. This relationship is based on the finding of increased growth rates among chinook salmon rearing in the vicinity of tidal marshes; however, such studies come from research conducted north of the San Francisco Estuary. In this ecosystem, the benefits of slow-moving, shallow estuarine habitats have not been demonstrated despite efforts to document them (Brown 2003). Although productive, tidal marsh habitats in Suisun Marsh may be too warm to support increased salmonid growth rates. The impact of tidal marsh habitats on the success of salmonid juveniles must be established through research efforts.

Creation of tidal marsh habitat is likely to produce additional foraging and reproduction habitat for a variety of land birds and rails, including the black rail and the California clapper rail. Many species would benefit from riparian habitat, which may colonize the interface between upland and wetland. Also, upland transitional habitat may provide important refugia for the salt marsh harvest mouse, habitat for a range of uncommon plant species, connectivity with upland habitat types, and refugia for a variety of species under changing climate conditions.

13.3.2.2 Constraints

The primary constraints identified by this conceptual analysis are a reduction in managed wetland area and impacts on waterfowl hunting, availability of sediment supply, water quality degradation, impacts on existing infrastructure and other assets, and social/transaction costs.

Although much of the Marsh surface is subsided, restoration would result in a conversion of wetland habitat type, values, and functions. Uncertainty is associated with the time frame for tidal Marsh plain evolution and the lower-elevation sites (e.g., the Grizzly Island sites) may remain a sub-tidal habitat for years. The higher-elevation sites (e.g., in Regions 2 and 4) are currently above mean sea level and therefore should re-vegetate rapidly.

Reduction in Managed Wetland Area and Impacts on Waterfowl Hunting

One of the primary Marsh land uses at present is waterfowl habitat and hunting. A significant constraint to the conversion of managed wetland to tidal wetland would be the reduction in suitable waterfowl habitat. The foregone revenue from lost hunting may be significant and additional hunting pressure may occur on the remaining managed wetlands. These lost revenues may be regarded as a cost of tidal wetland restoration.

Estimates of waterfowl hunting fees for wetlands in the Suisun Marsh are in the range $15 to $100 per hunting day[4]. In assessing the likely number of hunting days for a particular island, the Context Memorandum: Recreation (Iteration 1) was consulted (Delta Vision Blue Ribbon Task Force 2007). The information in this document showed that private clubs in the Suisun Marsh area had about 60,000 waterfowl recreation user-days during the 2006 season.[5] If we consider that these clubs cover approximately 60,000 acres, then this level of hunting can be thought of as 1 waterfowl recreation user-day per acre.[6] At a conservative estimate of $15 to $100 per recreational user-day, the potential opportunity cost is $15 to $100 per acre.

Availability of Sediment Supply

The sediment supply available to restore tidal wetlands in Suisun Marsh varies temporally and spatially. The ability of sediment to accumulate in a newly breached tidal wetland depends on

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[4] According to the CDFG's License and Review Branch, a Type-A one day entry permit for the 2006/2007 waterfowl season cost $14.75, which we rounded to $15.00. In a May 5, 2005, article in *Western Farm Press* titled "Sacramento Valley Rice Growers Winter Flood, Ducks Keep Coming," Harry Cline stated that duck club hunters are "willing to pay as little as $1,500 to as much as $5,000 or more per person per season"; $5,000/13 hunting season weeks x 3 days = $128.21 per day is the maximum rate that duck club hunters are willing to pay. We rounded $128.21 to $100.00 for a more conservative value.

[5] In the Context Memorandum: Recreation (Delta Vision Blue Ribbon Task Force 2007), Pat Graham and Steve Chappell of the Suisun Resource Conservation District estimated that the 158 duck clubs of the Suisun Marsh were open an average of 3 days per week, 13 weeks per year (i.e., 39 hunting days a season). Graham and Chappell multiplied this number of hunting days by an assumed number of hunters per day (10) for each of the 158 duck clubs in Suisun Marsh. The resulting value was 61,620 recreation user-days per year for the duck clubs in Suisun Marsh. We rounded this result to 60,000 for a more conservative value.

[6] Of the 85,000 acres of habitat land in Suisun Marsh, the state owns 10,487 acres and duck clubs own approximately 70,000 acres, most of Suisun Marsh's waterfowl habitat.

particle size, water velocity, and settling time, among other factors. Sediment may be suspended in fluvial outflow, or incoming tides may scavenge sediment from adjacent channels, mudflats, or other locations in the estuary. Nurse Slough transports a larger sediment load than other Suisun Marsh sloughs (Wilcox, pers. comm.).[7] Also, the shallow areas of Grizzly Bay may be a sediment source because of the opportunity for wind and water movement to suspend sediment.

Water Quality Degradation

The findings of the Suisun Marsh Levee Investigation Report indicate that the salinity impact of levee breaches in Suisun Marsh is a complex function of breach size, breach location, and the total inundation volume (CALFED 2000). The modeling study showed that large (5,000-foot) breaches on Suisun Bay tend to increase salinity over a wide area of Suisun Bay and the Delta, regardless of the breach location. Small (100-foot) breaches result in locally elevated salinity levels, but generally reduce salinity further away from the breach site. Small levee breaches away from main channels (e.g., off tidal sloughs) or near shallow-water habitats tend to reduce overall salinity more than small breaches adjacent to deep channels and bays. For example, the model predicts a significant increase in salinity in Suisun Bay and the west Delta as a result of a small levee breach on Van Sickle Island when the breach occurs on the relatively deep-water Sacramento River. From these potential salinity impacts, the study found that levees positioned along Suisun Bay and deep-water channels such as the Sacramento River should be carefully managed if salinity control is a primary management objective.

Salinity increases may also necessitate increased management activity in the managed wetlands to avoid increased salt loading to the managed wetlands and decreased life expectancy of water control facilities and infrastructure.

Other potential risks of tidal restoration on water quality include the cycling and methylation of mercury and the production of reactive dissolved organic material. Methylmercury, which is produced through a process referred to as methylation, in which inorganic mercury is converted through microbial activity, is toxic to wildlife and humans. The production of reactive dissolved organic material may pose hazards to drinking water quality. These wetland processes and by-products warrant further study.

Impacts to Infrastructure and Other Assets

An additional potential constraint to large-scale tidal restoration would be the loss of existing infrastructure and assets, including roads, railroads, below- and aboveground utility lines, gas drilling pads, and water management structures (Brown 2004). The Impact to Infrastructure Technical Memorandum, which was prepared for Phase 1 of the Delta Risk Management Strategy (URS 2007f) estimated the density of infrastructure and assets within analysis zones for the entire Marsh and Delta. Asset classes included major and minor roads, highways, railways, transmission lines, solid waste substations, highway bridges, oil and gas assets, dwellings, commercial/industrial facilities, and “other.” The analysis zones in the technical memorandum

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[7] This characteristic is one of the reasons for locating the restoration complexes for management regions 2 and 4 adjacent to Nurse Slough.

and the conceptual areas identified in this analysis are not congruous. Therefore, it is not possible directly assess the impacts of large-scale tidal restoration using the data from the technical memorandum. However, we calculated order-of-magnitude estimates by estimating the percent overlap between the conceptual restoration areas and the analysis zones in the technical memorandum. Preliminary estimates based on these analyses suggest that the value of assets within the conceptual restoration areas ranges from a few hundred dollars in Region 4 to approximately $7,000 in Region 3. The assets are listed and valued by conceptual restoration area in Table 13B-1 in Appendix 13B. In developing the conceptual design for large-scale tidal wetlands within the Marsh, it has been assumed that these assets would be abandoned in place. No attempt was made to estimate the cost of decommissioning, dismantling, or relocating these assets. Additional fine-scale analyses would be necessary to determine the actual value of the assets in each conceptual restoration area.

Social/Transaction Costs

Where substantial land use change is to occur, and where people and their livelihoods are affected, considerable social costs can be assumed to occur. Given the cultural values associated with existing commercial and recreational uses in Suisun Marsh, considerable community opposition to the conversion of managed wetlands into unmanaged tidal wetlands is likely. However, it is beyond the scope of this analysis to assess the magnitude of these social costs.

13.4 COST ESTIMATE

The capital costs shown in Table 13-10 include land acquisition, levee breaching, levee lowering, starter channel excavation, new levee construction, and levee upgrades (to Suisun Marsh Levee Specifications). As discussed above, considerable social and transaction costs would be likely with efforts to convert diked managed wetlands to tidal wetlands. However, these costs are not assessed as part of this cost estimate. The cost basis is described above, with the exception of land acquisition costs. Total costs for property acquisition in Suisun Marsh were assumed to be $3,600/acre[8] based on estimates of the purchase of Meins Landing and Blacklock by the Department of Water Resources (Gaines, pers. comm., 2007). Some costs have been determined in other building block analyses and are being used uniformly across the building blocks, as follows:

- $5 per cubic yard for earthmoving (excluding fill import costs)
- Mobilization and demobilization costs of 10 percent of construction cost
- Contingencies of 30 percent
- Survey, design, construction management, and administration costs of 30 percent

The largest costs are attributed to land acquisition, construction of new levees, and levee upgrades to the Suisun Marsh Levee Specifications standards. The full cost estimate calculations are presented in Tables 13C-1 and 13C-2 in Appendix 13C.

[8] Costs are less for the conceptual area in Region 3 because most of the land (Grizzly Island Wildlife Area) is already owned by CDFG. See full cost calculations (Appendix 13C).

13.5 RISK REDUCTION

The purpose of this building block is habitat enhancement; however, some risk reduction is also associated with this building block.

- The upgrade of levees to Suisun Marsh Levee Specifications standards reduces the risk of failure and the consequent risk to managed wetland habitat and species.
- Breaching levees to restore tidal action decreases the area subject to potential catastrophic failure.
- Reduced hydrostatic pressure from tidal restoration would help to offset some of the increase in hydrostatic pressure due to the ongoing subsidence on managed lands. The results of the salinity and hydrodynamics modeling conducted for the CALFED Suisun Marsh Levee Investigation Report indicated that the creation of large tracks of inundated land "dissipates tidal energy resulting in diminished tidal range and tidal excursion" (CALFED 2000). Thus, the addition of approximately 5,900 acres of tidally inundated lands would reduce hydrostatic pressure on the remaining exterior levees in Suisun Marsh. The magnitude of this decrease may depend on the exact sizes and locations of the restored tidal wetlands and levee breaches. Therefore, detailed hydrodynamic modeling would be required to estimate the magnitude of this impact and the impacts on water quality.
- Risk reduction may also accrue when this building block, together with other building blocks, is incorporated into the scenarios.

13.6 FINDINGS AND CONCLUSIONS

13.6.1 Findings

Large scale tidal wetland restoration in Suisun Marsh is under consideration by many entities. This conceptual analysis is based on numerous assumptions, as described throughout the text. Our assessment of the potential to restore tidal wetlands in Suisun Marsh suggests that restoration would be most cost-effective in island complexes; however, significant detailed studies and design would be required to confirm these findings.

The tidal restoration costs range from $3,000 to $9,000 per acre, including land acquisition, design, new levee construction, levee upgrades, mobilization/demobilization, and contingencies. The estimated cost of restoring 5,900 acres of tidal wetland is $32.5 million, and the estimated cost for the enhancement of 25,000 acres of managed wetland is $135 million. Both of these estimates include mobilization, contingencies, and design costs. The total cost estimate for this building block is about $167 million.

Considerable potential exists to enhance and diversify Suisun Marsh habitats to contribute to the recovery of special-status species. However, this opportunity may be accompanied by the constraints of loss of diked managed wetland habitats, wildlife populations, hunting areas, and significant impacts to water quality, including increased salinity. The breaching of levees and the restoration of lands to tidal action would reduce the risk of catastrophic levee failure and reduce the long-term costs of levee maintenance and repair.

Many opportunities exist for research to accompany tidal restoration and enhancement efforts, including the effects of such efforts on water quality conditions, the use of the restored and enhanced areas by various biota, and the impacts of the efforts on various biota.

13.6.2 Conclusion and Recommendations

This analysis is intended to identify **conceptual-level** costs, benefits, and constraints based on **hypothetical** large-scale tidal wetland restoration and managed wetland enhancements within Suisun Marsh. Any attempt to identify specific land parcels for restoration or to estimate the potential impacts of specific restoration projects would require additional fine-scale analysis with consideration of accurate topography, sediment loads and transport, Marsh hydrodynamics, and land ownership. Further development of any of these alternatives should be based on detailed feasibility analysis, planning and background data gathering and evaluation, and integration with ongoing planning initiatives. Opportunities for acquisition or placement of conservation easements on contiguous properties of the size considered in this analysis would involve a considerable amount of negotiation and time.

Tables

Table 13-1 List of Special-Status Sensitive Species in Suisun Marsh
(Source: Table 1 in SMCPA 2007)

Species	Listing Status
Plants or Plant Communities	
Alkali milk-vetch (*Astragalus tener var. tener*)	CNPS 1B
Delta tule pea (*Lathyrus jepsonii var. jepsonii*)	CNPS 1B
Mason's lilaeopsis (*Lilaeopsis masonii*)	State Rare; CNPS 1B
Soft bird's beak (*Cordylanthus mollis ssp. mollis*)	State Rare; Federal Endangered
Suisun Marsh aster (*Symphyotrichum lentum*)	CNPS 1B
Suisun thistle (*Cirsium hydrophilum var. hydrophilum*)	Federal Endangered; CNPS 1B
Reptiles	
Western pond turtle (*Clemmys marmorata*)	State CSC
Bird Species or Groups	
California black rail (*Laterallus jamaicensis coturniculus*)	State Threatened & Fully Protected
California clapper rail (*Rallus longirostris obsoletus*)	State Endangered; Federal Endangered
Suisun song sparrow (*Melospiza melodia maxillaris*)	State CSC
Saltmarsh common yellowthroat (*Geothlypis trichas*)	State CSC
Northern harrier (*Circus cyaneus*)	State CSC
Great egret (*Ardea alba*)	CDF Sensitive
Swainson's hawk (*Buteo swainsoni*)	State Threatened
Western least bittern (*Ixobrychus exilis hesperis*)	State CSC
Fish	
Steelhead trout (*Oncorhynchus mykiss*)	Federal Threatened
Delta smelt (*Hypomesus transpacificus*)	Federal Threatened; State Threatened
Green sturgeon (*Acipenser medirostris*)	Federal Threatened: State CSC
Longfin smelt (*Spirinchus thaleichthys*)	State CSC
Sacramento splittail (*Pogonichthys macrolepidotus*)	State CSC
Winter-run Chinook salmon (*Oncorhynchus tshawytscha*)	Federal Threatened; State Threatened
Spring-run Chinook salmon (*Oncorhynchus tshawytscha*)	Federal Threatened; State Threatened
Fall-run Chinook salmon (*Oncorhynchus tshawytscha*)	State CSC
Pacific Groundfish	Essential Fish Habitat
Coastal Pelagics	Essential Fish Habitat
Chinook salmon habitat	Federal Critical Habitat; Essential Fish Habitat
Mammals	
Salt marsh harvest mouse (*Reithrodontomys raviventris*)	Federal Endangered; State Endangered
Suisun ornate shrew (*Sorex ornatus sinuosus*)	State CSC

Table 13-2 Key Agencies and Groups Managing Suisun Marsh

(Source: Table 1 in Brown 2004)

Agency/Organization	Description of Responsibilities in Managing Suisun Marsh
Suisun Resource Conservation District (SRCD)	The SRCD has the primary local responsibility for regulating and improving water management practices on privately owned lands within the primary management area of the Suisun Marsh.
California Department of Water Resources (DWR)	Although DWR has several functions relating to Suisun Marsh Management, its involvement in the marsh is mainly associated with operation of the State Water Project (SWP) and mitigation of any adverse effects.
California Department of Fish and Game (CDFG)	CDFG manages 12,000 acres of managed wetlands in the marsh for hunting, fishing, and other recreational uses, administers California Endangered Species Act activities to protect special-status species, and manages habitat intended to mitigate for SWP and other impacts.
U.S. Bureau of Reclamation (USBR)	The USBR operates the Central Valley Project (CVP), which diverts water from the southern Delta through the Tracy Pumping Plant and works with DWR, CDFG, and the Suisun Resource Conservation District (SRCD) to avoid, minimize, or mitigate for its impacts in the Marsh.
Bay Conservation and Development Commission (BCDC)	The BCDC is specifically charged with protecting the Suisun Marsh, the largest remaining wetland in California, by administering the Suisun Marsh Preservation Act in cooperation with local governments.
California State Water Resources Control Board (SWRCB)	Through its water quality and water rights authorities, the SWRCB promulgates water quality standards for the Suisun Marsh and conditions DWR and USBR water rights permits to meet those standards.
U.S. Fish and Wildlife Service (USFWS)	As part of its Endangered Species Act (ESA) authority, the USFWS issues biological opinions on operation of the state and federal water projects, including those facilities in the Marsh (e.g., the MSSCG) and may require other federal permits be conditioned to protect listed species.
National Oceanic and Atmospheric Administration (NOAA) Fisheries	NOAA Fisheries has federal ESA responsibility for anadromous fish, including winter and spring chinook salmon and steelhead, and has conditioned operation of the MSSCG and water diversions in the Marsh to protect these species.
CALFED Bay-Delta Authority (CALFED)	The 2000 CALFED Record of Decision (ROD) calls for creation of an additional 5,000 to 7,000 acres of tidal wetlands in Suisun Marsh. Through its Ecosystem Restoration Program, CALFED funds Marsh restoration projects.
Charter Group	The Suisun Marsh Charter and its multi-agency member group were established in 2000 to develop a regional plan that balances implementation of the CALFED program with other preservation, management, and restoration programs in the Marsh.
Solano Mosquito Abatement District	To limit mosquito production in wetlands the Solano Mosquito Abatement District may restrict the time when ponds can be flooded in the fall.
The U.S. Army Corps of Engineers (USACE)	The USACE issues permits to DWR, CDFG, and SRCD for work in the Marsh, including facilities (404 permits) and maintenance (Regional General Permits). These permits contain conditions designed to protect water quality and sensitive species.

Table 13-3 Significant Policies Affecting Marsh Actions
(Source: Table 3 in SMCPA 2007; note: acronyms defined in Table 13-2)

Action	Year	Description
Four-Agency Memorandum of Agreement	1970	Called for studies necessary to obtain a thorough understanding of the requirements of fish and wildlife resources and evaluate alternative means of providing substitute freshwater supplies that would enable protection and enhancement of marsh waterfowl.
The Nejedly-Bagley-Z'Berg Suisun Marsh Preservation Act	1974	Required the BCDC to develop a plan for the Marsh and provides for various restrictions on development within Marsh boundaries.
Suisun Marsh Protection Plan, The Suisun Marsh Preservation Act of 1977 (Assembly Bill 1717)	1976, 1977	Adopted the Suisun Marsh Protection Plan, which defines and limits development within primary and secondary management areas, and designates the BCDC as the state agency with regulatory jurisdiction of the Marsh and calls for the Suisun Resource Conservation District to have responsibility for water management in the Marsh.
SWRCB Water Rights Decision 1485	1978	Set salinity standards and required DWR and USBR to develop and fully implement a plan to meet the standards.
Plan of Protection for the Suisun Marsh	1984	Prepared by DWR and USBR in response to SWRCB D-1485. The plan proposed construction of large facilities and distribution systems in six phases to meet salinity standards. Two of the six phases were completed, including the Initial Facilities (including Morrow Island Distribution System, Roaring River Distribution System, and Goodyear Slough outfall) in 1981 and the Suisun Marsh Salinity Control Gates in 1989.
Suisun Marsh Preservation Agreement (SMPA)	1987	A contractual agreement between DWR, USBR, CDFG, and SRCD. Requires DWR and USBR to meet salinity standards, sets a timeline for implementing the Plan of Protection, and delineates monitoring and mitigation requirements.
Bay-Delta Accord	1994	State and federal agencies, working with agricultural, environmental, and urban stakeholders, reached agreement on water quality standards and related provisions that would remain in effect for 3 years.
SWRCB Water Quality Control Plan	1995–1998	Modified the Suisun Marsh salinity objectives. Modeling analysis by the Suisun Marsh Planning Program showed that changes in Delta outflow objectives and fish protection flow standards would be met most of the time at all Suisun Marsh compliance stations. Some standard exceedances would be expected in the Western Marsh that participants to the SMPA agreed could be mitigated by more active water control by landowners.
SWRCB Water Rights Decision 1641	1999	Updated salinity standards for Suisun Marsh. Increased outflow and salinity requirements for the Bay-Delta. Provided indirect benefits to the Suisun Marsh. SWRCB did relieve USBR and DWR of its responsibility in meeting salinity objectives at S-35 and S-97 in the western Marsh.
CALFED Suisun Marsh Charter	2000	Intended to develop a regional plan that balances implementation of the CALFED Program, SMPA, and other management and restoration programs within Suisun marsh in a manner responsive to the concerns of stakeholders and based on voluntary participation by private landowners.
Revised Suisun Marsh Preservation Agreement	2005	In 2005 the SMPA was revised due to significant events and changes in conditions, including: operation of the Suisun Marsh Salinity Control Gates, issuance of D-1641, and release of the CALFED Record of Decision.

Table 13-4 Suisun Marsh Existing Habitat Composition by Planning Region

Suisun Marsh Habitats	Region 1	Region 2	Region 3*	Region 4	Bays/Sloughs	Total
Tidal	2,066	1,966	2,949	644		7,624
Diked managed wetlands and uplands	11,888	7,266	28,628	2,968		50,750
Minor sloughs	245	332	697	43		1,316
Developed	164	12	45	2		223
Riparian	24	<1	0	0		24
Upland	3,336	6,590	3,522	3,005		16,452
Bays and major sloughs					25,664	25,664
Total acres	17,721	16,165	35,841	6,662	25,664	102,053

Source: Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (SMCG n.d.).

* In the previous draft of this report, region designations 1 through 4 followed those in draft planning documents (maps and tables) provided to URS by CDFG. However, comments received by URS indicated that Regions 3 and 4 were mislabeled based on the most up-to-date planning information. In the current report, Regions 3 and 4 have been reversed to maintain consistency with the region designations of the draft Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (SMCG n.d.).

Table 13-5 Target Acreages for Tidal Restoration

Planning Region	Total Area in Region (acres)	Minimum Restoration Target (acres)	Midpoint Restoration Target (acres)*	Maximum Restoration Target (acres)
Region 1	17,721	500	1,375	2,250
Region 2	16,165	460	1,265	2,070
Region 3	35,841	860	2,365	3,870
Region 4	6,662	180	495	810
Total	102,053	2,000	5,500	9,000

* Minimum and maximum restoration targets based on alternatives presented in the Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (SMCG in preparation). The midpoint restoration target was calculated by URS to facilitate the conceptual-level analyses presented in this report.

Table 13-6 Total Area and Levee Lengths for Conceptual Restoration Areas

Planning Region	Midpoint Restoration Target (acres)*	Conceptual Restoration Area (acres)	Length of Abandoned Flood Control Levees (miles)	Length of Exterior Levees for Upgrade (miles)	Length of New Flood Protection Levees (miles)
Region 1	1,375	1,422	9.3	0.7	0.5
Region 2	1,265	1,462	13.6	0.0	0.4
Region 3	2,365	2,317	9.2	0.0	6.7
Region 4	495	730**	4.1	0.8	0.0
Total	5,500	5,931	36.2	1.5	7.6

* See Table 13-5.
** Total land area of Bradmoor Island. Actual area of tidal wetland formation would be less given the presence of extensive upland habitat on the island.

Table 13-7 Total Area and Planned Improvements in Conceptual Managed Wetland Enhancement Areas

Managed Wetland Areas for Enhancement	Total Length of Exterior Levee Upgrade (miles)*	Total Area of Managed Wetland Enhancement (acres)**	Number of Water Control Structures	Number of Fish Screens
Region 2 (Upper Joice Island)	10.6	2,233	12	0
Region 3 (Grizzly Island)	46.6	22,954	78	13
Total	57.2	25,187	90	13

* Excluding levees designated as abandoned, constructed, or updated in order to implement tidal restoration on Grizzly and Joice Islands (see Figure 13-8).

** Excluding areas designated for tidal restoration (see Figure 13-9).

Table 13-8 Tidal Datum for Montezuma Slough at Suisun Slough Cut

Tide	Feet (NAVD88)
Mean higher high water (MHHW)	5.58
Mean high water (MHW)	5.02
Mean sea level (MSL)	3.03
Mean low water (MLW)	1.15
Mean lower low water (MLLW)	0.56

Source: DWR 2004.

Table 13-9 Existing Elevations (LiDAR 2006)

Planning Region	Approximate Levee Crest Elevation (feet) (NAVD88)	Approximate Land Surface Elevation Adjacent to the Levee Crest Point (feet) (NAVD88)
Region 1	10	3
Region 2	10.5	3
Region 3	11.25	2
Region 4	11	3

NAVD88 = North American Vertical Datum of 1988

Table 13-10 Conceptual-Level Capital Costs of Building Block 3.1: Suisun Marsh Tidal Wetland Restoration

	Land Acquisition				Levee Breaching		Levee Lowering		Channel Excavation		New Levee Construction			Upgraded Levees			
Planning Region	Total Area (acres)	Unit Cost ($/acre)	Cost ($)	Earthmoving Unit Cost ($5/CY)*	Total Volume (CY)	Cost ($)	Total Volume (CY)	Cost ($)	Total Volume (CY)	Cost ($)	Total Length (mi)	Unit Cost ($1.45M/ mi)	Cost ($)	Total Length (mi)	Unit Cost ($1M/mi)	Cost ($)	Total Cost ($)
Region 1	1,422	$3,600	$5,119,200	$5	0	$0	198,891	$994,454	0	$0	0.5	$1,450,000	$725,000	0.7	$1,000,000	$700,000	$2,419,454
Region 2[a]	1,462	$3,600	$3,888,000	$5	3,262	$16,310	334,627	$1,673,137	26,282	$131,410	0.4	$1,450,000	$580,000	0	$1,000,000	$0	$2,400,857
Region 3[b]	2,317	$3,600	$1,951,200	$5	8,311	$41,555	274,159	$1,370,795	29,930	$149,649	6.7	$1,450,000	$9,715,000	0	$1,000,000	$0	$11,276,999
Region 4	730	$3,600	$2,628,000	$5	0	$0	114,879	$574,397	0	$0	0	$1,450,000	$0	0.8	$1,000,000	$800,000	$1,374,397
Total	5,931	---	$13,586,400	---	11,573	$57,865	922,557	$4,612,783	56,212	$281,059	8	---	$11,020,000	2	---	$1,500,000	$17,471,707

a = of the total 1462 acres, 382 are in public ownership and are not included in acquistion costs
b = of the 2,317 total acres, 1775 acres are already in public ownership and are not included in acquisition costs

Conceptual Costs of Managed Wetland Enhancement

	Water Control Structures			Upgraded Levees			
Conceptual Managed Wetland Enhancement Area	# Water Control Structures	Unit Cost ($)	Cost ($)	Total Length (mi)	Unit Cost ($1M/mi)	Cost ($)	Total Cost ($)
Grizzly Island	78	$170,000	$13,260,000	46.6	$1,000,000	$46,600,000	$59,860,000
Upper Joice Island	12	$170,000	$2,040,000	10.6	$1,000,000	$10,600,000	$12,640,000
Total	90	---	$15,300,000	57.2	---	$57,200,000	$72,500,000

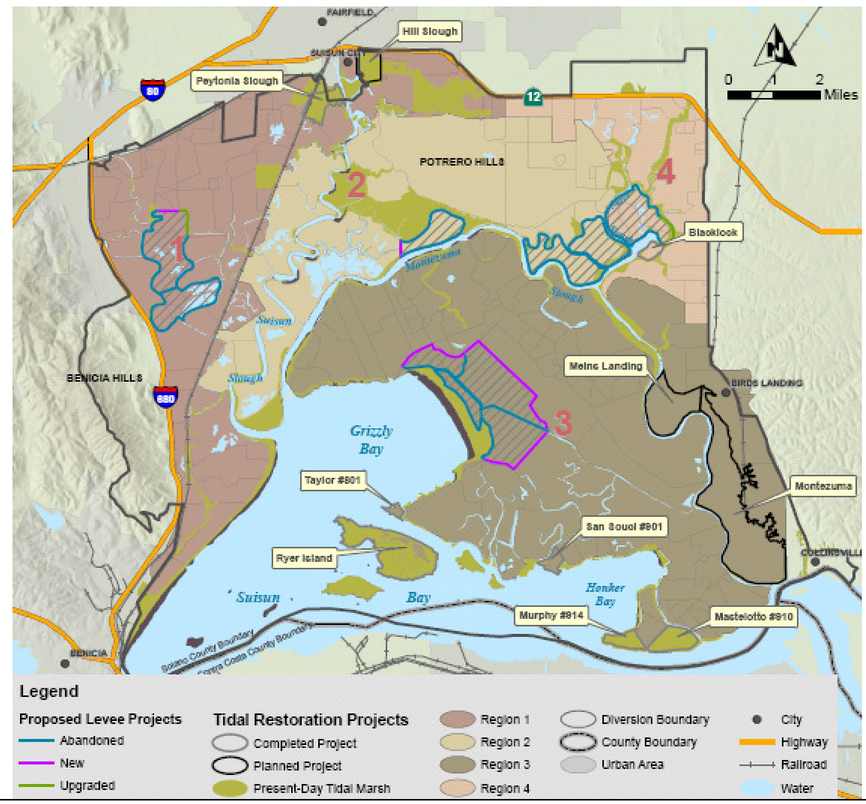
MANAGED WETLAND ENHANCEMENT SUBTOTAL $72,500,000

TIDAL WETLAND RESTORATION SUBTOTAL	$17,471,707
MANAGED WETLAND ENHANCEMENT SUBTOTAL	$72,500,000
TIDAL WETLAND RESTORATION AND MANAGED WETLAND ENHANCEMENT SUBTOTAL	$89,971,707
Mobilization/Demobilization (10%)	$8,997,171
SUBTOTAL	$98,968,878
Contingencies (30%)	$29,690,663
SUBTOTAL	$128,659,541
Surveys, design, CM and administration, etc.(30%)	$38,597,862
GRAND TOTAL	$167,257,403

NOTES:
*Earthmoving unit cost ($5/cubic yard) applies to Levee Breaching, Levee Lowering, and Channel Excavation

Figures

Suisun Marsh: Past (ca. 1800) and Present Tidal Wetland Extent	**Planned, Completed, and Targeted Suisun Marsh Tidal Wetland Restoration Projects**



Suisun Marsh

Area (acres):

- Suisun Marsh total area: 102,053 acres
- Managed marsh: 50,750 acres
- Tidal wetland: 7,624 acres

Tidal Wetland Restoration Activities:

Areas previously restored to tidal wetland in Suisun Marsh include:

- Murphy #914, San Souci #901 , Mastelotto #910, Taylor #801, Ryer Island, Peytonia Slough, Blacklock

Areas currently planned for tidal wetland restoration include:

- Hill Slough West, Meins Landing and the Montezuma Wetlands

The Habitat Management, Preservation, and Restoration Plan for Suisun Marsh (SMCG n.d.) and associated Programmatic EIR/EIS target restoration of 2,000 to 9,000 acres of tidal marsh.

Planning Region	Total Area (acres)	Minimum Restoration Target (acres)	Midpoint Restoration Target (acres)	Maximum Restoration Target (acres)
1	17,721	500	1,375	2,250
2	16,165	460	1,265	2,070
3	35,841	860	2,365	3,870
4	6,662	180	495	810
Total	102,053	2,000	5,500	9,000

Restoration Criteria:

- Average site elevations should be at or above mean sea level (3.03 ft NAVD88) to promote formation of tidal wetlands.
- Sites should provide connectivity with adjacent upland transitional habitats.
- Sites should provide connectivity with adjacent tidal wetland habitats.
- Site design should maintain existing levels of flood protection.
- Current ownership should not be considered in site selection.

Restoration Area	At or Above MSL?	Connects to Upland Habitat?	Connects to Tidal Marsh?	Maintains Flood Protection?
Region 1	yes	no	no	yes
Region 2	yes	yes	yes	yes
Region 3	yes	no	yes	yes
Region 4	yes	yes	yes	yes

About the Building Block:

Definition

- Managed wetlands and other diked lands would be converted to tidal wetlands and remaining wetlands would be enhanced.

Objectives

- Provide habitat for tidal marsh-dependent special-status species and other native species.
- Take advantage of lower subsidence rates, higher elevations, and availability of adjacent upland transitional habitats to restore sustainable habitat continuum from tidal marsh to upland habitat.
- Minimize salinity effects on the Delta from tidal restoration.
- Enhance remaining managed wetlands through structural levee improvements and water circulation improvements, including replacement/repair of tide gates and installation of fish screens.

Benefits

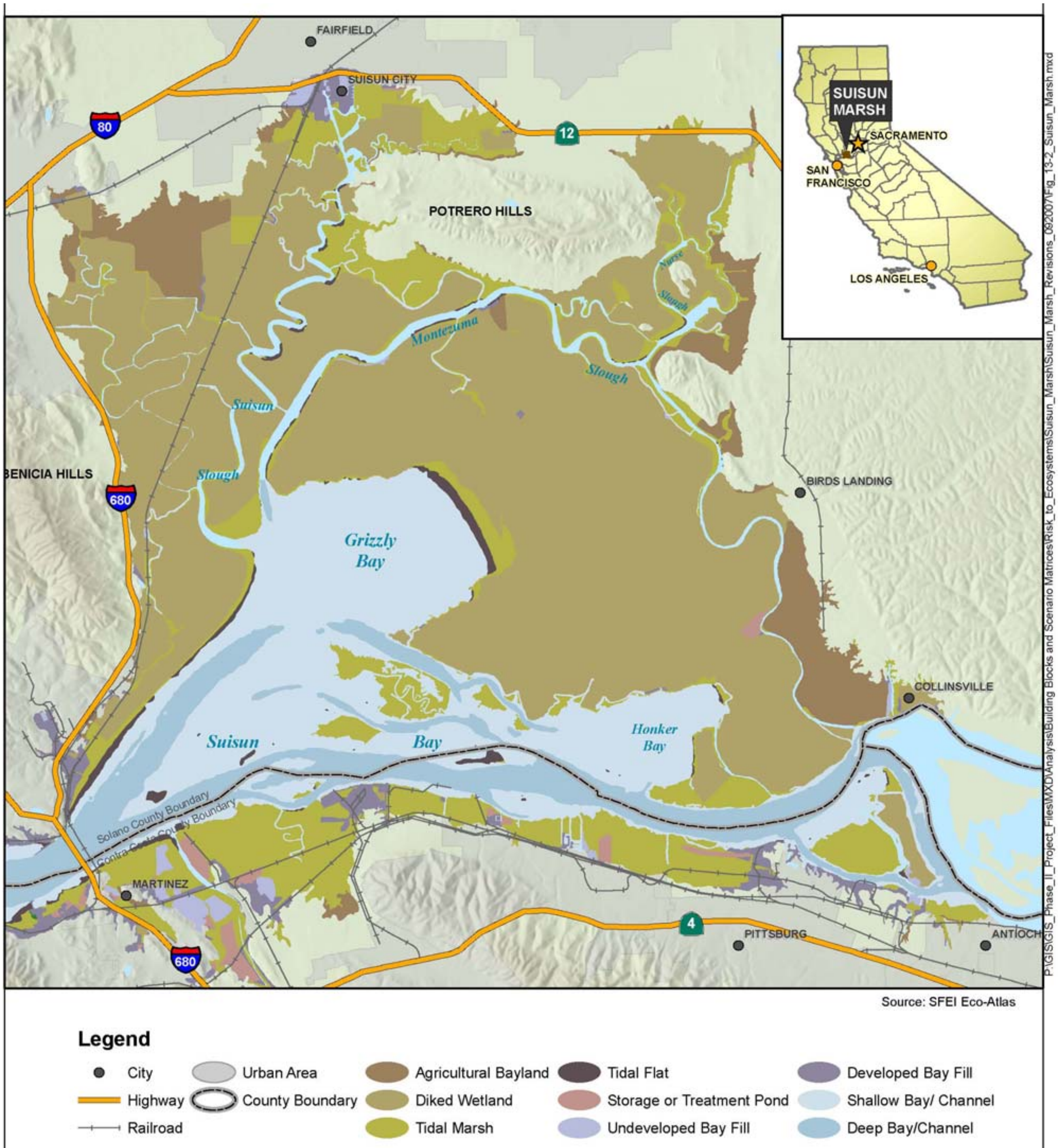
- *A*dditional habitat for sensitive species, including Delta smelt (*Hypomesus transpacificus*), black rail (*Laterallus jamaicensis cotorniculus*), and California clapper rail (*Rallus longirostris obsoletus*).
- Increased primary and secondary production, with possible benefits for consumer organisms such as fish.
- Mitigation of potential impacts of levee failures associated with floods, subsidence, sea-level rise, and seismic events.
- Habitat restoration and revegetation would occur relatively quickly compared with many western Delta islands because existing elevations are higher.

Consequences

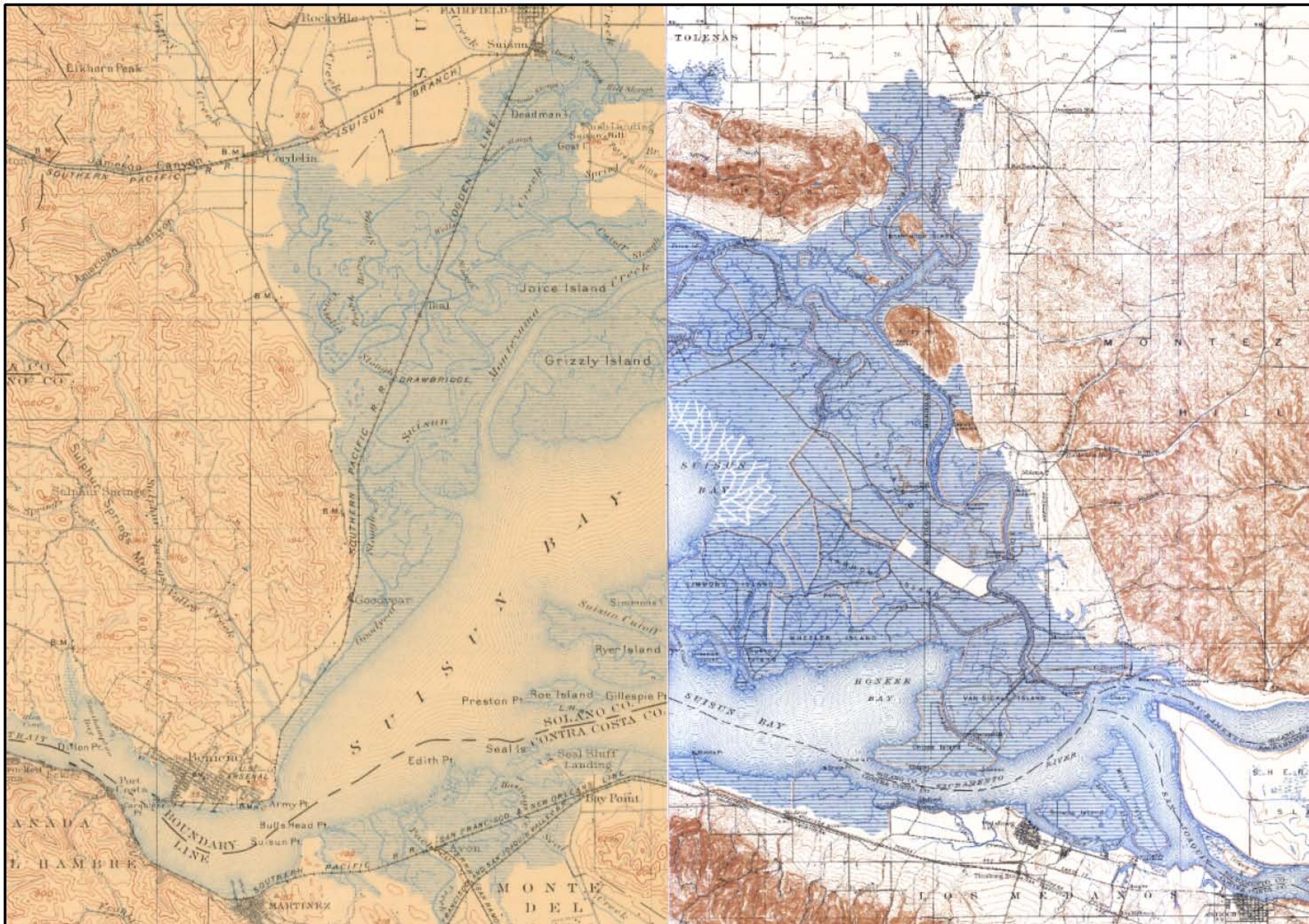
- Conversion from managed to tidal wetland may reduce habitat availability for wildlife, including waterfowl and terrestrial species (e.g, tule elk *[Cervus canadensis nannodes]*).
- Conversion from managed to tidal wetland would reduce number of acres in traditional duck clubs.
- Conversion from managed to tidal wetland may impact water quality (e.g., increased salinity, mercury methylation, and dissolved organic carbon) in Suisun Bay and theSacramento–San Joaquin River Delta.

Major Cost Components

- Restoration construction: Re-alignment of flood protection levees.
- Levee enhancement: Upgrade to Suisun Marsh levee standards
- Managed wetland enhancement: Gate replacement, water conveyance improvement, levee upgrades, and fish screen installation.
- Land acquisition: $3,600/acre.
- Total project cost: about $167 million for restoration of approximately 5,900 acres of tidal wetland and enhancement of approximately 25,000 acres of managed wetland.



URS	DRMS	Suisun Marsh Region	Figure 13-2
	26815935		August 2007

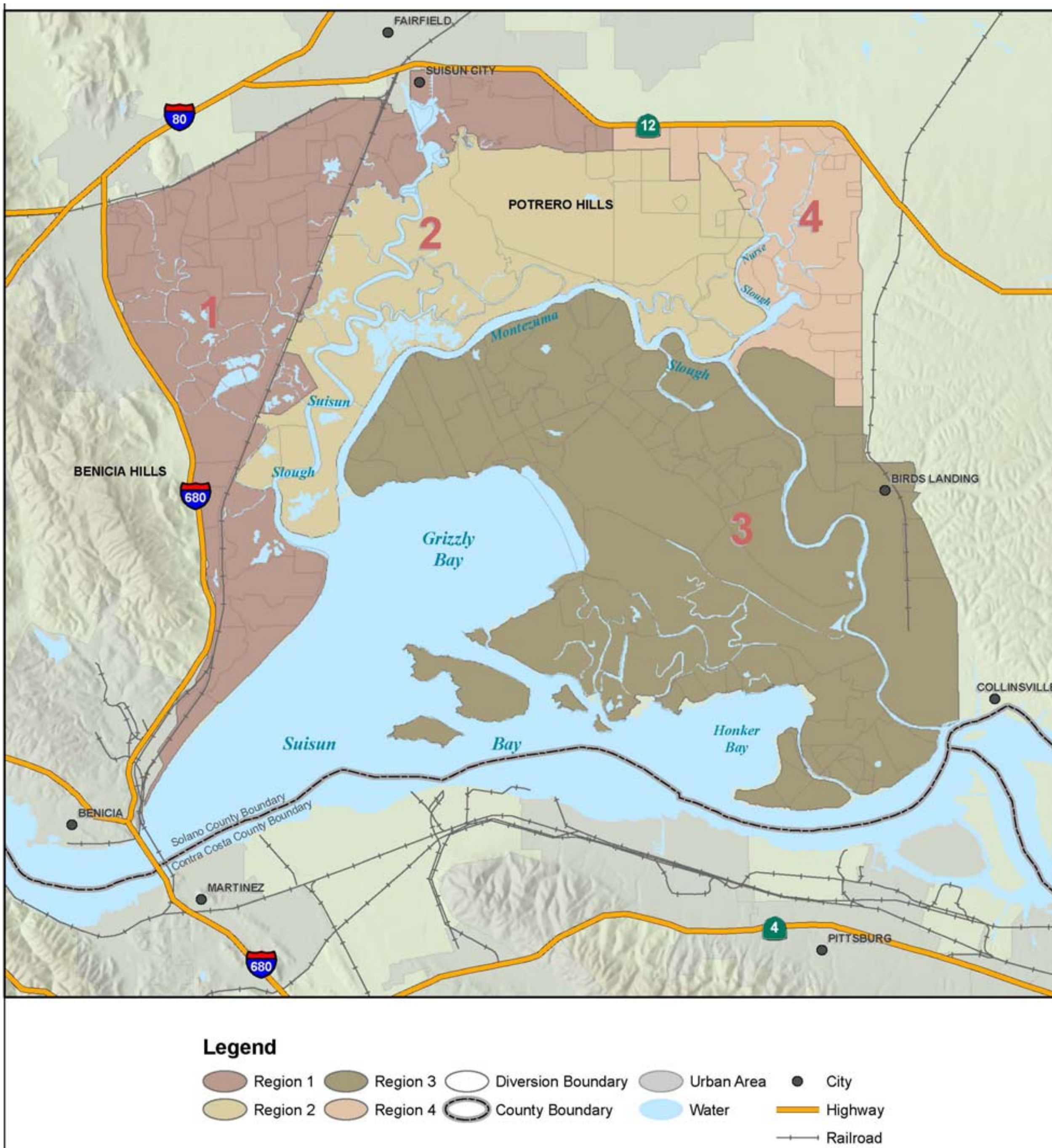


0 1 2 Miles Scale 1:144,000

Map sources:
Western half - U.S. Geological Survey, Napa 1:125,000-scale topographic map, Edition of May 1902, reprinted March 1913
Eastern half - U.S. Geological Survey, Antioch 1:62,500-scale topographic map, Edition of November 1908, reprinted 1951

URS	DRMS	Historical Map of Suisun Bay and Marsh (map dates 1902 and 1908)	Figure 13-3
	26815935		August 2007


FAIRFIELD
Hill Slough
SUISUN CITY
Peytonia Slough
80
12
POTRERO HILLS
Blacklock
Nurse Slough
Montezuma Slough
Suisun Slough
BENICIA HILLS
680
Meins Landing
BIRDS LANDING
Grizzly Bay
Grizzly Island Wildlife Area
Montezuma
Taylor #801
San Souci #901
COLLINSVILLE
Ryer Island
Suisun Bay
Honker Bay
BENICIA
Solano County Boundary
Contra Costa County Boundary
Murphy #914
Mastelotto #910
MARTINEZ
4
PITTSBURG
680
Source: SFEI Eco-Atlas
Legend
Historical Tidal Marsh
Present-Day Tidal Marsh
Present-Day Tidal Flat
Historic Bay Extent
Present-Day Bay Extent
Urban Area
Tidal Restoration Projects
Completed Project
Planned Project
Diversion Boundary
Public Land
County Boundary
City
Highway
Railroad
0 1 2 Miles
URS
DRMS
26815935
Suisun Marsh Region
Existing Conditions
Figure 13-4
August 2007



0 1 2 Miles

URS	DRMS	Suisun Marsh Planning Regions	Figure 13-5
	26815935		August 2007

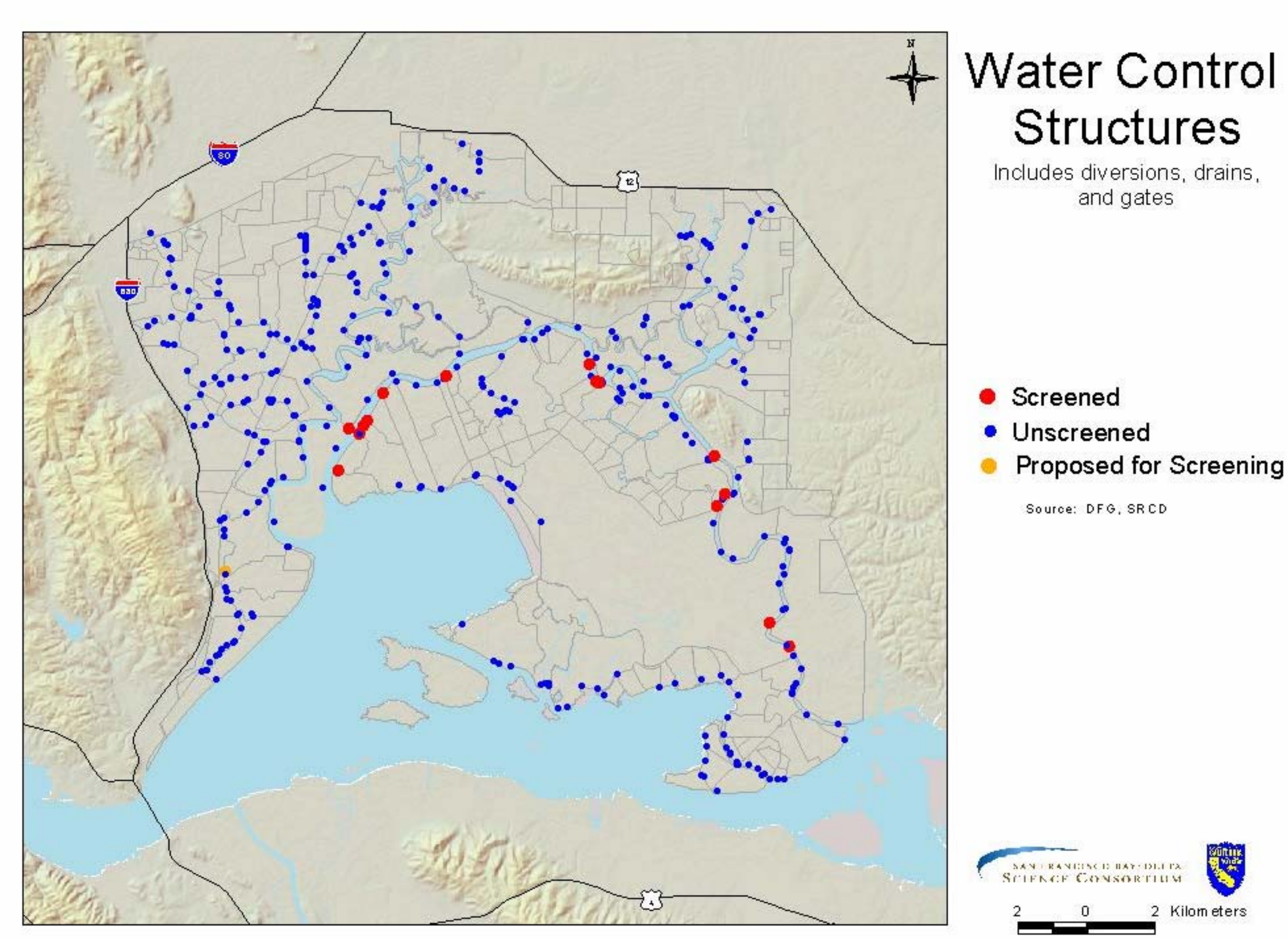


Figure 13-6 Water Control Structures in Suisun Marsh

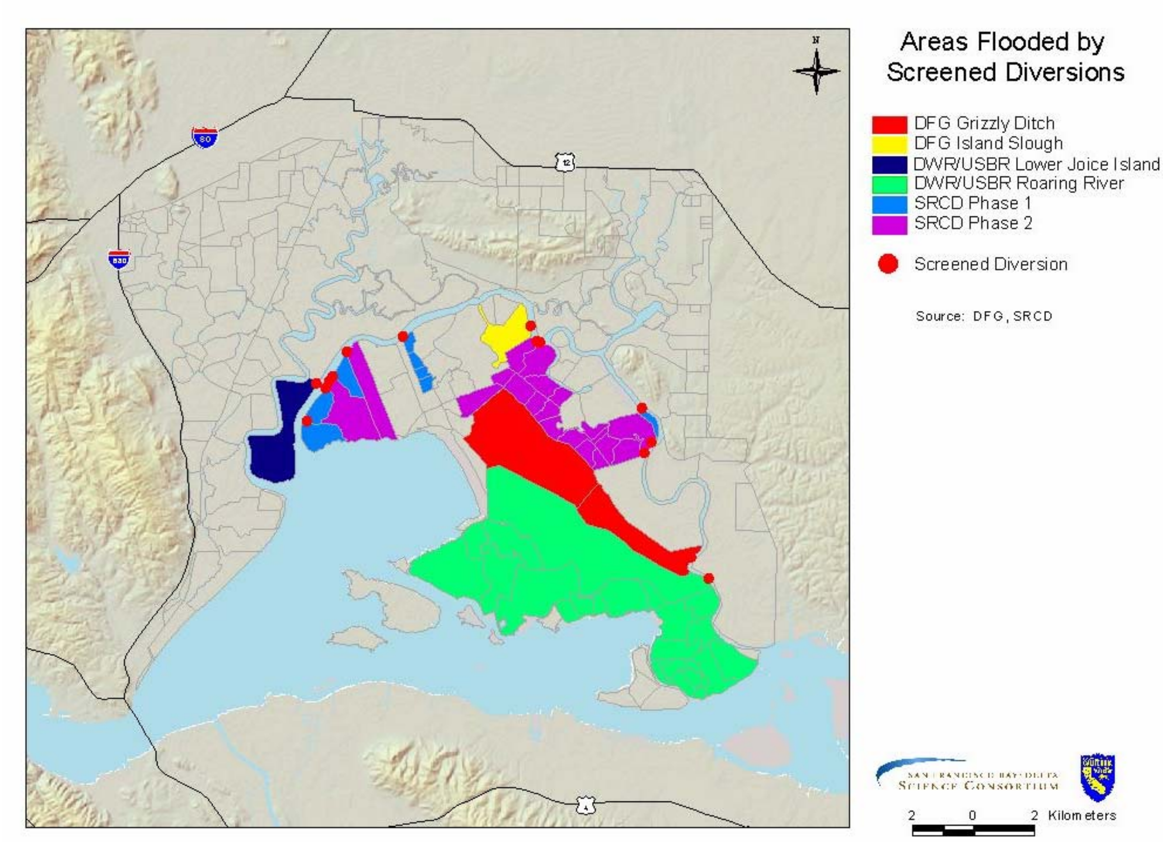
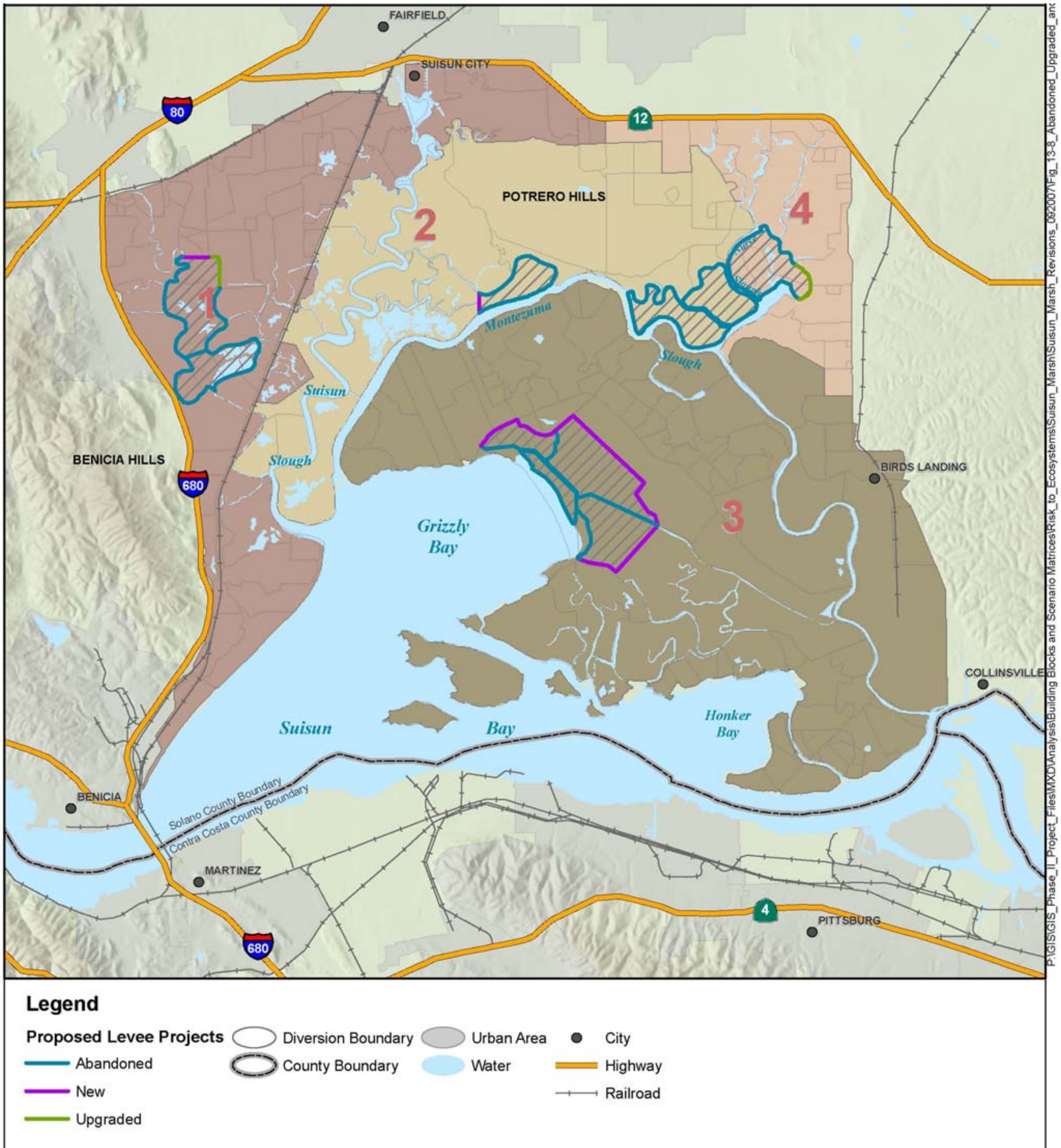


Figure 13-7 Areas in Suisun Marsh Flooded by Screened Diversions

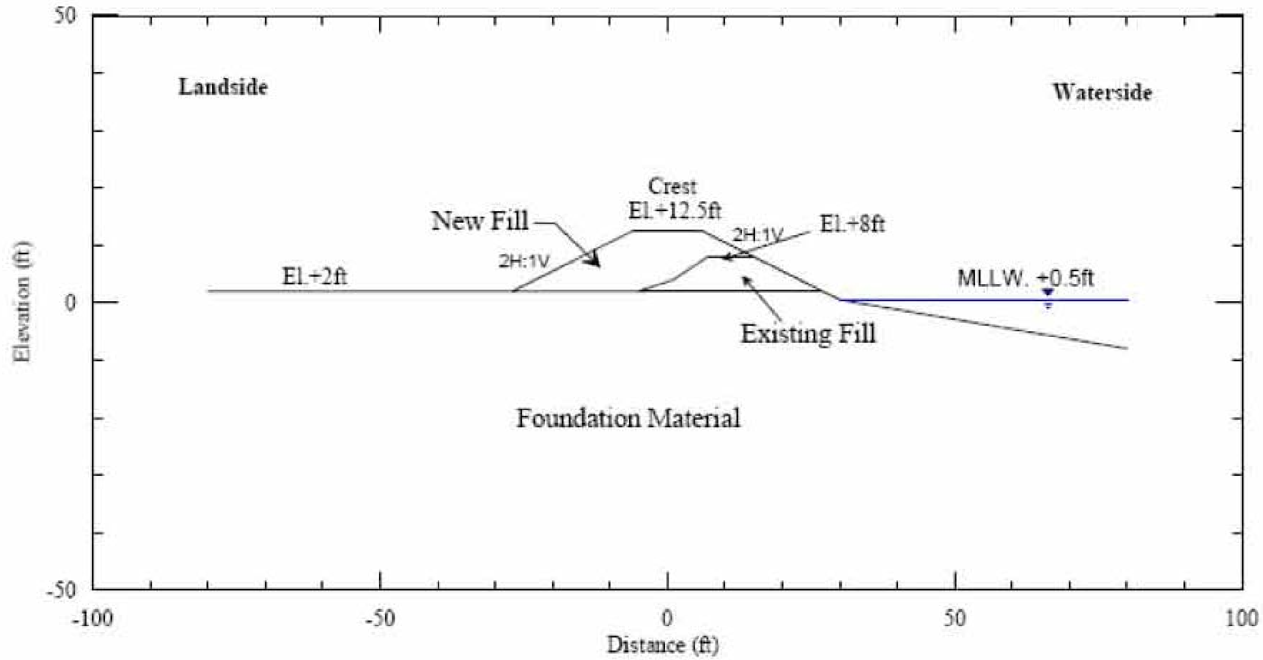


URS	DRMS	Location of Abandoned, New, and Upgraded Levees in Conceptual Restoration Areas	Figure 13-8
	26815935		August 2007


FAIRFIELD
SUISUN CITY
80
12
POTRERO HILLS
1
2
3
4
Nurse
Slough
Montezuma
Slough
Suisun
Slough
BENICIA HILLS
680
BIRDS LANDING
Grizzly
Bay
COLLINSVILLE
Honker
Bay
Suisun
Bay
BENICIA
Solano County Boundary
Contra Costa County Boundary
MARTINEZ
4
PITTSBURG
680
Legend
Proposed Levee Projects
Upgraded
Diversion Boundary
County Boundary
Urban Area
Water
City
Highway
Railroad
0 1 2 Miles
URS
DRMS
26815935
Location of Abandoned, New, and Upgraded Levees in Conceptual Managed Wetland Enhancement Areas
Figure 13-9
August 2007

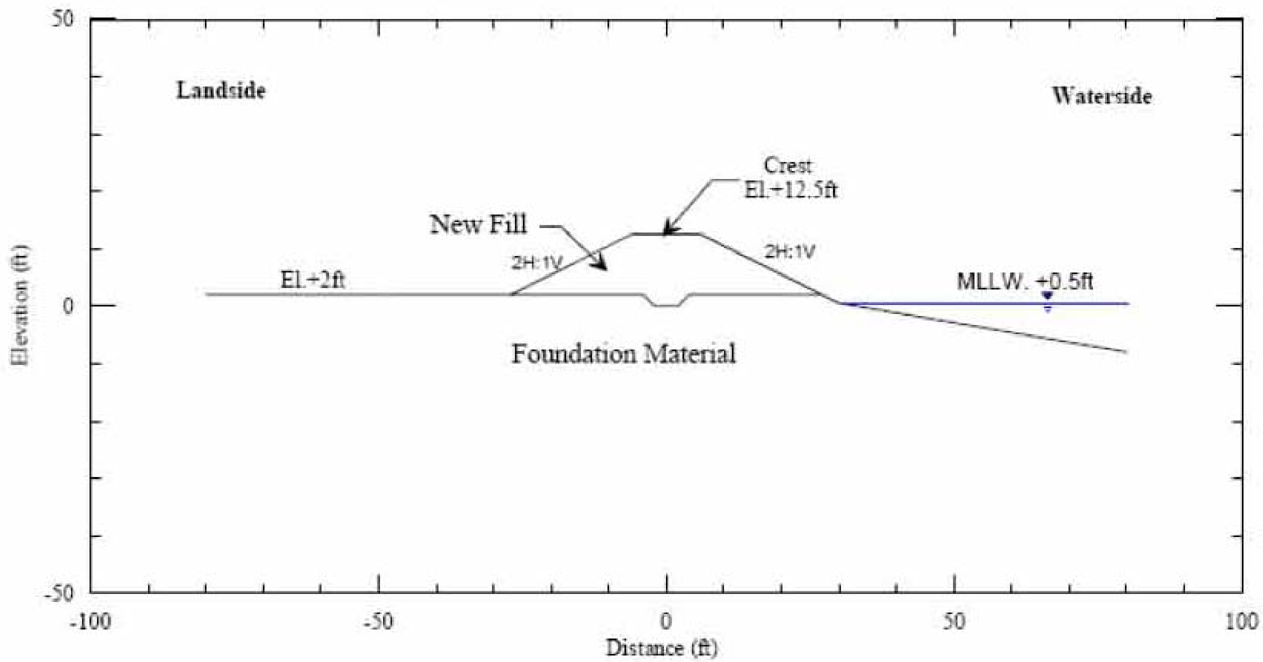
Appendix 13A

Levee Cross Sections: Suisun Marsh Levee Specifications



Note:
Datum- NAVD88
Levee crest El. = MLLW El. + 9 ft water height + 2 ft freeboard + 1ft wave run-up

URS	Project No. 26815935 Delta Risk Management Strategy (DRMS) Task Order No.13	Parametric Cross Section Suisun Marsh Levee Specification - Levee Upgrade	Figure 13A-1



Note:
Datum- NAVD88
Levee crest El. = MLLW El. + 9 ft water height + 2 ft freeboard + 1ft wave run-up

URS	Project No. 26815935 Delta Risk Management Strategy (DRMS) Task Order No.13	Parametric Cross Section Suisun Marsh Levee Specification - New Levee	Figure 13A-2

Appendix 13B

Value of Infrastructure and Assets in Conceptual Restoration Areas

Table 13B-1
Infrastructure and Assets in Suisun Marsh

Planning Region	Analysis Zone	% of Analysis Zone	Minor Roads	Major Roads	Highways	Railway	Transmission lines	Sub stations - solid waste	Hwy Bridge	Oil - gas wells	Gas Fields	Gas / Petroleum Pipelines	Dwellings - family	Dwellings - other	Commercial / Industrial	Other	Total Asset Value ($,000)
			miles	miles	miles	miles	miles	count	count	count	acres	miles	count	count	count	count	$
Region 1	SM-40	100	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$1,556
Region 1	SM-47	100	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$0
Total			1.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**$1,556**
Region 2	SM-58	100	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$768
Region 2	SM-51	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	$0
Region 2	SM-133	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	203.3	0.0	0.0	0.0	0.0	0.0	$0
Total			0.7	0.0	0.0	0.0	0.0	0.0	0.0	9.0	205.8	0.0	0.0	0.0	0.0	0.0	**$768**
Region 3	SM-85-Grizzly Is.	36	3.1	0.0	0.0	0.0	0.0	0.0	0.0	4.3	68.3	2.2	1.8	0.0	0.0	0.0	$6,096
Region 3	SM-56	22	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.7	0.0	0.0	0.0	$827
Total			3.3	0.0	0.0	0.0	0.0	0.0	0.0	4.8	68.3	2.6	2.5	0.0	0.0	0.0	**$6,923**
Region 4	SM-43	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	94.4	0.0	1.0	0.0	0.0	0.0	$252
Total			0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	94.4	0.0	1.0	0.0	0.0	0.0	**$252**

Appendix 13C

Cost Calculations

Table 13C-1
Levee Breach Cost Calculations

Planning Region	Total Conceptual Restoration Area (acres)	Approx. Land Surface Elevation Adjacent to Levee Crest Point (ft NAVD88)	Approx. Levee Crest Elev NAVD88 (ft)	MHW minus Land Surface Elevation (ft)	Tidal Prism (acre ft)	Total Length of Breach Required (ft)	Bottom of Breach (MLLW Elev) (ft)	Levee Crest Width (ft)	Total Volume (CY)	Earth Moving Cost ($5/CY)
Region 1	1,422	3	---	---	---	---	---	---	---	$0.00
Region 2	1,462	3	10.5	2.02	2,953	738	0.56	12	3,262	$16,308.45
Region 3	2,317	2	11.25	3.02	6,997	1,749	0.56	12	8,311	$41,556.42
Region 4	730	3	---	---	---	---	---	---	---	$0.00

*Levee lowering only

Levee Lowering Cost Calculations

Planning Region	Total Conceptual Restoration Area (acres)	Length of Abandoned Water Control Levees (miles)	Approx. Levee Crest Elev NAVD88 (ft)	Lowered Levee Elevation (MHW Elev) (ft)	Levee Crest Width (ft)	Total Volume (CY)	Earth Moving Cost ($5/CY)
Region 1	1,422	9.3	10	5.02	12	198,891	$994,454.21
Region 2	1,462	13.6	10.5	5.02	12	334,627	$1,673,137.04
Region 3	2,317	9.2	11.25	5.02	12	274,159	$1,370,794.93
Region 4	730	4.1	11	5.02	12	114,879	$574,396.81

Channel Excavation Cost Calculations

Planning Region	Approx. Levee crest elevation (ft NAVD88)	Approx. Land Surface Elevation Adjacent to Levee Crest Point (ft NAVD88)	MLW (ft)	Cut Depth (Elevation Difference) (ft)	Channel Area (Breach Width by 250 ft long) (sq ft)	Channel Volume (cu ft)	Total Volume (CY)	Cost ($5/CY)
Region 1	10	3	1.15	1.85	0	0	0	$0
Region 2	10.5	5	1.15	3.85	184,500	710,325	26,282	$131,410
Region 3	11.25	3	1.15	1.85	437,250	808,913	29,930	$149,649
Region 4	11	3	1.15	1.85	0	0	0	$0

Levee Costs for Conceptual Restoration Areas

Planning Region	Length of New Flood Protection Levees (miles)	New Levee Cost ($1.5M/mile)	Length of Exterior Levees for Upgrade (miles)	Upgraded Levee Cost ($1M/mile)	Total Levee Cost
Region 1	0.5	$750,000	0.7	$5,600,000	$6,350,000
Region 2	0.4	$600,000	0.0	$0	$600,000
Region 3	6.7	$10,050,000	0.0	$0	$10,050,000
Region 4	0.0	$0	0.8	$6,400,000	$6,400,000

Levee Costs for Managed Wetland Enhancement

Managed Wetland Areas for Enhancement	Total Area of Managed Wetland Enhancement (acres)	# of Water Control Structures	# of Fish Screens	Total Length of Exterior Levee Upgrade (miles)	Upgraded Levee Cost ($1M/mile)
Grizzly Island	22,582	78	13	46.6	$46,600,000
Upper Joice Island	2,233	12	0	10.6	$10,600,000
Total	24,815	90	13	57.2	$57,200,000

Table 13C-2
Suisun Marsh Levee Specifications Standard

DEPARTMENT OF WATER RESOURCES
DELTA RISK MANAGEMENT
SUISUN MARSH SPECIFICATION (1980)

09/21/07

Item No.	DESCRIPTIONS	QTY	UNIT	UNIT Cost	TOTAL Cost
1	**UPGRADING EXISTING LEVEE TO SUISUN MARSH SPECIFICATION (1980)**				
	COST PER FOOT				
	CLEAR AND GRUBB	1.0	LF	5.00	$ 5
	EARTHWORK (ON-ISLAND SOIL)	12.0	CY	8.00	$ 96
	EXCAVATION		CY		$ -
	SEEDING		LF		$ -
	SUBTOTAL SITE WORK				**$ 101**
	MOBILIZATION 10%				$ 10
	CONTINGENCIES 30%				$ 33
	SURVEYS, DESIGN, CM AND ADMINISTRATION 30%				$ 43
	COST PER FOOT				**$ 188**
	UPGRADE COST PER MILE				**$1,000,000**

1	**CONSTRUCTING NEW LEVEE TO SUISUN MARSH SPECIFICATION (1980)**				
	COST PER FOOT				
	CLEAR AND GRUBB	1.0	LF	5.00	$ 5
	EARTHWORK (ON-ISLAND SOIL)	17.5	CY	8.00	$ 140
	EXCAVATION	0.5	CY	5.00	$ 3
	SEEDING		LF		$ -
	SUBTOTAL SITE WORK				**$ 148**
	MOBILIZATION 10%				$ 15
	CONTINGENCIES 30%				$ 49
	SURVEYS, DESIGN, CM AND ADMINISTRATION 30%				$ 63
	COST PER FOOT				**$ 274**
	NEW LEVEE CONSTRUCTION COST PER MILE				**$ 1,450,000**